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(54) **A system for transmitting packet data in radio telephone TDMA systems**

System zur Datenpaketübertragung in einer TDMA-Telefunkanordnung

Système de transmission de paquets de données dans un système téléphonique radio TDMA

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Description

[0001] This invention relates to the transmission of packet data having flexible variable rate reservation access for TDMA-based cellular systems.

[0002] Typically, cellular systems offer efficient data and speech services based on circuit switched technology. In circuit switching, however, the use of transmission resources is not optimal since the transmission link is maintained for the whole duration of the connection independent of whether or not information is being sent at a given moment. Transmission resources are also shared by many other users, and therefore maintaining a circuit switched connection for one user unnecessarily wastes the transmission resources for other users. The fact that data services are transmitted in bursts is also a disadvantage in circuit switching. Channel utilization can be improved and optimized by using packet switched transmission of information.

[0003] There have been several research projects to study packet radio for optimizing the use of channels in burst data traffic. Time division multiple access (TDMA) was not utilized in older systems. More recent research projects have studied time division based packet radio systems capable of reserving multiple time slots per use; in other words, capable of data transmission with high data rates.

[0004] A future third generation cellular system called the universal mobile telecommunication system (UMTS) has to be capable of performing both circuit switched and packet transmission, like integrated services digital network (ISDN) transmission and asynchronous transfer mode (ATM) transmission. The key factor is an air interface utilizing advanced multiple access technology for efficiently multiplexing, at the air interface, channels supporting various types of services to and from the radio path. Requirements set by the UMTS system for the air interface have been described in the article "A Reservation Based Multiple Access Scheme for a Future Universal Mobile Telecommunications System" by J.M. DeVille, published in the Mobile and Personal Communications, 13-15 December 1993, Conference Publication No. 387, IEE 1993. The multiple access has to be capable of utilizing the inactivity of the information source by assigning a physical channel only when there is activity on the logical channel and, furthermore, be capable of supporting various bit rates so that, when necessary, time slots in a frame are assigned for the logical channel.

[0005] To meet these and other requirements a multiple access control method has been proposed called packet reservation multiple access (PRMA + +) which is part of the proposal for third-generation cellular systems in relation to the transmission of packeted speech and data. The PRMA + + can be used as multiple access control both in packet switched and circuit switched transmission. The PRMA + + method concentrates on the use of one time slot in the transmission of packet data. This mechanism provides an efficient multi-slot/multi-user environment for a system having a high number of time slots in its TDMA frame.

[0006] The PRMA + + uses time division multiple access TDMA in the radio channel. This makes it possible for a user to share radio channel transmission resources. Now follows a description of this system, with reference to Figure 1. A TDMA frame is divided into time slots in which a transmitted burst carries data and signalling associated with channel coding, detection, etc. In the uplink direction, ie. from a mobile station to a network (base station), there are two types of time slots: reservation time slots, or, R-slots which are used only for transmitting channel request bursts; and information time slots, or, I-slots used only for transmitting information bursts. In a channel request burst a mobile station uses a so-called air interface channel identifier including the mobile station's network address that identifies the logical channel and requesting one or more time slots of a frame for its use according to the need at that moment. In the downlink direction, ie. from a network (base station) to a mobile station, there are also two types of time slots: I-slots for transmitting information and A-slots, or, acknowledge time slots. When a mobile station requests access to the network, the base station acknowledges the request with A-slots by sending the requesting station's address and the number of the I-slot. From then on, that I-slot is reserved for the mobile station.

[0007] Let the number N of PRMA ++ time slots available in one TDMA frame be a system configuration parameter. Then, in the uplink channel there is in one TDMA frame, one reservation time slot (R-slot) and N-1 information time slots (I-slots). All mobile stations begin transmission by sending a channel request in the R-slot and if several mobile stations use the same R-slot for sending the request, collisions may occur. In the downlink channel, there is also in a TDMA frame, in addition to the I-slots and the above-mentioned A-slot for acknowledging channel reservation requests sent in the R-slot, a fast paging time slot (FP-slot) for informing a mobile station about an incoming data transmission and the information transmission time slots.

[0008] A mobile station initiates a connection by sending a channel request on an uplink channel, in the R-slot used for this purpose by all mobile stations of a cell. The base station acknowledges the channel request with a downlink acknowledge burst in the A-slot. If no requests are sent in the R-slot or if there are collisions on the channel recognized by the base station, it sends an "idle" flag in the acknowledge burst of the corresponding A-slot and then the mobile station knows that it should send the channel request again after a while. In the case that a channel request sent in the R-slot was received without problems but there are no free time slots for transmission, the mobile station will be informed about the matter in the next downlink acknowledge time slot. The mobile station will queue for access until a free time

slot is found.

[0009] An R-slot includes a training sequence, the address of the mobile station, the number of requested information time slots, and the circuit switching flag. The flag tells whether the reservation is valid for the duration of the packet or for a longer time. The channel is reserved until an instruction is given to release the reservation. The acknowledge burst in the A-slot includes the address of the mobile station requesting a channel and the channels dedicated for traffic. The mobile station receives the acknowledge burst and then sets the receiver and transmitter to the defined channel. Traffic on the channel is begun and it continues as long as there are data or speech to transmit. In packet data transmission, the number of bursts - or, in this case, packets - sent after one channel request can be fixed.

[0010] A base station uses the fast paging time slot (FP-slot) to inform a mobile station about an incoming packet. A mobile station listens to the fast paging channel and decodes all incoming messages to find its own code. The fast paging time slot includes a list of the I-slots that have been allocated to the mobile station. A mobile station acknowledges a paging call by sending an acknowledge in the fast paging acknowledge time slot (FP-ack).

[0011] Accordingly, it is characteristic of the proposed UMTS system that both uplink and downlink connections that are inactive at a given moment are not allocated physical channels during that time, which prevents unnecessary use of resources. Channels are always reserved using the same method independent of whether the connection is a circuit switched or a packet connection. One disadvantage of this known system is that the allocation of channels is not dynamic and, therefore, it is not easy to change the channels reserved for packet use. The reservation, paging, and acknowledge time slots are certain time slots and prior art systems take no position in the changing of those time slots. In addition, the known system does not particularly take into account the symmetry or asymmetry of the packet transmission when setting up a transmission channel. Hence, there is the disadvantage of the system not being very flexible. It is true the system is good with a great number of time slots but with a variable number of time slots, say, one or two, the system is not easily configurable.

[0012] A TDMA system according to the prior art is disclosed in "The Performance of CELLPAC : A Packet Radio Protocol Proposed for the GSM Mobile Radio Network" by B. Walke et al., MRC Mobile Radio Conference, published 13. 11. 1991.

[0013] According to the present invention there is provided a time division multiple access (TDMA) radio telephone system in accordance with claim 1.

[0014] This has the advantage that each logical channel reserved for packet data transmission is independent of any others. Thereby, facilitating the variation by a network of the number of packet data channels available to users. Thus, a network can dynamically allocate channels for packet data transmission according to need. Thus, only channels needed for packet data transmission are reserved as such.

[0015] In a preferred embodiment the control channel (C) includes an acknowledge/retransmission request burst (ARQ) for indicating error-free received data. Thus, if error-free data was not received or the data could not be reconstructed, retransmission of the data can be requested.

[0016] Preferably, the logical channel is a downlink logical channel for transmitting from the base station to the mobile station, and the control channel (C) is capable of transmitting packet paging (PP) data for informing the mobile station of incoming packet data.

[0017] Optionally, the control channel (C) is capable of transmitting a packet access grant PAG signal for acknowledging a channel reservation request (PRA) transmitted from the mobile station. Thus, the control channel is capable of acting as a reservation request acknowledge channel.

[0018] This invention proposes a flexible system in which time slots reserved for packet data can be changed according to need.

[0019] The multi-slot concept described below is based on channel independence: all physical radio channels are alike and one or more channels, up to the maximum number, can be dedicated for packet use. The media access control (MAC) algorithm of the layer above the physical layer is independent of the number of time slots in use. So the operator is free to launch the packet data transmission service using only a few time slots in a TDMA frame and, as the need arises, to upgrade the service using all time slots in a TDMA frame. If the application is e.g. GSM or DCS 1800 or some such derivative, one frame includes 8 time slots and it is therefore possible to dedicate from one to eight time slots for packet data use. Even if the network supports multi-slot transmission a mobile station is still free to use only one time slot. Then even a simple mobile station is able to use the packet data service provided by the network.

[0020] A high-capacity cell can be built by dedicating more than one carrier wave for the packet radio service. The algorithm is independent of the number of time slots dedicated by the operator. An operator can start with one time slot and upgrade the service up to 8 time slots when the number of packet radio users grows.

[0021] Naturally, the number of carriers can also be increased, which means that multiple independent carriers are used.

[0022] An embodiment in accordance with the invention is described below, by way of example only, with reference to the enclosed drawings, and in which:

Figure 1 shows the frame structure of the proposed UMTS system;

Figure 2 shows the logical channel structure in a

system in accordance with the invention;

Figure 3 shows the channel structure of a system using eight time slots;

Figure 4 shows the structure of the combined paging and acknowledge time slot;

Figure 5 shows an example of the bit contents of the fields presented in Figure 4;

Figure 6 shows an example of the structure of the paging time slot;

Figure 7 shows an example of the bit contents of the paging time slot;

Figure 8 shows the structure of the packet access grant time slot,

Figure 9 shows an example of the bit contents of the packet access grant time slot;

Figure 10 shows the structure of the packet random access burst;

Figure 11 shows an example of the bit contents of the packet random access burst;

Figure 12 shows the signalling chart of mobile originated packet transmission;

Figure 13 shows the state transitions in mobile originated packet transmission;

Figure 14 shows the signalling chart of mobile terminated packet transmission;

Figure 15 shows the state transitions in mobile terminated packet transmission; and

Figure 16 shows variations of control time slots in a TDMA frame.

[0023] A "frame" in this description means consecutive time slots of a logical channel, not consecutive TDMA frames with their time slots unless specifically described as such, of which there are eight in the GSM system, for example.

[0024] Referring to Figures 2 and 3. Figure 3 shows downlink and uplink frames as seen from a base station in an 8-time-slot TDMA system. The structure in Figures 2 and 3 can be combined e.g. with GSM 51 multiframes if needed. In one of the TDMA frames going to the cell the base station sends only control data C, and all time slots of the next four frames include information I that can be packet data. In such a case, the number ot information frames per unit time is decreased, resulting in a decrease in information rate also.

[0025] Correspondingly, when the base station is receiving from the cell (uplink direction), one TDMA frame includes only control time slots C used for receiving requests, acknowledges, etc. sent by mobile stations. The next four TDMA frames include only time slots for receiving information I. Let us now consider the situation from the point of view of one mobile station. A base station sends control or information to one mobile station in the same time slot of each TDMA frame. So the time slots sent to one mobile station are the time slots marked with the dotted arrow a. Hence, the mobile station receives one control burst in the time slot C and, after that, information I in four consecutive bursts if there is information for that mobile. This sequence is called a frame in this description. Frames are received as long as there is something to receive. Correspondingly, a base station will receive from one mobile station in consecutive time slots marked with the dotted arrow b. The sequence consisting of a control time slot C and four consecutive information time slots I is called a frame in this description.

[0026] Figure 2 shows the (dedicated) frame structure. Uplink frames consist of time slots marked with the dotted arrow b in Figure 3 as explained above and, correspondingly, downlink frames consist of time slots marked with the dotted arrow a.

[0027] This description involves a case in which four bursts are used, as explained above, but an I frame may also be longer or shorter. A four-burst I frame is only one alternative and it is possible to use TDMA frames of another length (8 bursts, for example). This is an optimization problem: the longer the frame, the longer the access delay and minimum packet size. Thus, the length of the frame in the physical layer is a system parameter.

[0028] When encoding four-burst frames in the physical layer, it is possible to use the same coding as on the stand-alone dedicated control channel (SDCCH) in the known GSM system. This code has a frame length of four bursts, or 456 bits. (A 228-bit block consisting of 184 bits of user data, 40 parity bits, and 4 tail bits is convolutionally encoded into 456 bits.) The interleaving depth is 4. The interleaving depth of 4, compared to 19 in circuit switched data transfer, reduces the transmission delay and minimum packet size. Alternatively, some other code, like Reed-Solomon, could be used to encode the frames.

[0029] Let us now consider the physical layer, with reference to Figure 2 which should be interpreted as follows. If a base station is receiving packet data, the reception occurs in the gray I time slots. The base station sends an acknowledge in the downlink ARQ time slot. Hence, the connection is made up of the gray time slots. Correspondingly, when the base station is transmitting packet data, the connection is made up of the white time slots.

[0030] In layer 1 (the physical layer), an automatic retransmission request (ARQ) is used in a control time slot

C to decrease the frame error rate when transferring from the physical layer to the upper layers. However, the use of ARQ is optional and need not be utilised nor included in the system. A data frame consists of 4 bursts which have had the error correction coding and frame check done for them. In this example, every fifth burst both in the downlink and uplink directions is used for control purposes. The frequency of control bursts may of course be increased from the proposed every fifth, optimizing efficiency and the power consumption of the mobile station. In the downlink direction, a control burst, including a retransmission request ARQ, is transmitted as a normal burst. In the uplink direction, the ARQ is transmitted in an access-like burst with a long training sequence. Then the data part of the burst will not include a random number as usual but those bits will be replaced by ARQ bits. Hence, only a small part of an access-type control burst (here it is proposed 12 bits) is used for the retransmission request ARQ. A mobile station that does not know the exact timing advance is then able to transmit an ARQ burst. In the uplink direction, the control bursts include only ARQ bits.

[0031] Having transmitted the four-burst frame a transmitter/receiver will listen to the frame acknowledge. An erroneous frame will be immediately retransmitted and if the frame is correctly received, the transmission continues. The frames can be numbered to indicate the correct frames when requesting an automatic retransmission. The ARQ acknowledge has the same frame number which it will selectively acknowledge. It is even possible that every burst has a separately encoded block which is numbered.

[0032] The raw information bit rate is about 19.7 kbps on one TCH/F channel with this configuration. By using all eight TDMA time slots for one Mobile Station (MS) the raw bit rate is about 158 kbps. The automatic retransmission request is used over the radio path, ie. between a MS and base station BTS.

[0033] Above we discussed the physical layer in a system in accordance with the invention. Next we will have a look at the control layer MAC (multiple access control or media access control) above the physical layer. The control layer is used for transferring high level control messages. Still referring to Figure 3. The MAC algorithm is on top of layer 1, ie. every fifth burst is used for control purposes. Uplink and downlink channels are used asymmetrically and independently. The asymmetric use of a physical channel makes it possible to optimize the efficient use of channels. Data are usually sent in bursts with short intervals in one direction at a time. During another short interval the data flow may be in the opposite direction. This is carried out by separate channel allocation. Independence means that both uplink and downlink directions can be reserved independently of each other. The method can also be used symmetrically whereby uplink and downlink channels are reserved in pairs.

[0034] The high level control messages carried in the downlink control time slots C are packet paging P and packet access grant PAG. In the uplink, there is no special high level control time slot but a mobile station can send a packet random access (PRA) burst in any free I time slot to request a channel. In the physical layer, there is a special control time slot in the uplink direction and it is used for the ARQ.

[0035] Let us next consider a control time slot in the MAC layer. Both the packet paging P and the packet access grant PAG can be combined in one burst of a control time slot C or the paging and request may be sent in separate control time slots C. Having the packet paging P and the packet access grant PAG in the same control burst is the optimal case, and that is possible if the number of bits available in one burst in the cellular system is sufficient. Control bursts are encoded independently, ie. no interleaving is used.

[0036] Now referring to Figure 4 illustrating the first alternative, ie. the structure of a combined acknowledge and paging burst. A base station managing the radio resources monitors the states of the channels; in other words, which channels are free and which are reserved. It transmits a bitmap of free uplink channels in every downlink control burst as part of the burst; in Figure 4, right at the beginning of the burst. The bitmap indicates to the mobile station the idle channels at that moment on which it can send a packet channel request in the form of an access burst. Also included in the control burst are the packet paging, packet access grant, and the automatic retransmission request ARQ of the physical layer. The packet paging P part of the burst is used for informing the mobile station about incoming packet data transmission. The paging also includes the temporary packet mobile identity TMPI, temporary logical link identity TLLI in GSM GRPS, and a description of the channels reserved by the network for the mobile terminated data transmission. The third part of the control burst, the packet access grant PAG, includes a random number used to distinguish various requesters, a bitmap of the channels reserved for the connection, and the timing advance TA. The last part of the burst includes an ARQ for acknowledging layer 1 messages.

[0037] If the combined P and PAG burst were applied in the known GSM cellular system, the bit contents of the burst fields could be as shown in the exemplary table of Figure 5. The P and PAG together would take up 55 bits and ARQ 12 bits, thus making up a total of 67 bits in the burst. The combined burst can be used in any application system provided that the number of information bits in the burst is sufficient, ie. the number of information bits is the same or higher than in the GSM system.

[0038] Figures 6 and 8 illustrate another alternative for transferring paging and acknowledge bursts. The bursts are sent separately with the P and PAG in their own control bursts. The P and PAG time slots share the downlink control channel. These time slots are sent alternately, for example. Every other control time slot C is for the paging P and every other for the acknowledge

PAG. A mobile station will distinguish between paging and acknowledge by checking the steal bit in the burst. A P time slot will have "1" as the steal bit and a PAG time slot will have a "0" or vice versa. Occasionally there might be a need to send a packet access grant PAG instead of a packet paging P if there are no packet pagings coming to the cell at that moment. This can be done by stealing the P time slot for the PAG and notifying the mobile station with the steal bit.

[0039] As shown in Figure 6, the separate packet paging burst structure includes first the bitmap to indicate free/reserved channels. The bitmap consists of 8 consecutive bits if the TDMA frame is 8 time slots. The next field is the paging field in which the first part is the temporary mobile identity TMPI and the second part a bitmap which indicates to the mobile station the channels reserved by the network for the transmission of packet data, which the mobile station has to use for receiving packet data. Finally, there is the field for the automatic retransmission request. Figure 7 shows as an example the bit contents of the paging field when the cellular network is a GSM network. The field includes 60 bits if the TMPI is the GSM's temporary mobile subscriber identity TMSI. A shorter TMPI, 25 bits, for example, will suffice.

[0040] As shown in Figure 8, the separate packet access grant PAG burst includes first a bitmap to indicate free/reserved channels. The next field is the acknowledge field for the packet random access sent by a mobile station. There the first part is a random number included in the request sent by the MS. Then follows a bitmap that indicates to the mobile station the channels reserved by the network for the transmission of packet data. The mobile station will use these channels to send packet data. Finally, there is the field for the automatic retransmission request. The random number used in the request is used to indicate the packet access grant to a specific mobile station (mapping of PRA to PAG). Mobile stations in the cell will listen during this time slot and the random number will tell a particular mobile station that the acknowledge is meant for it. To decrease the probability of collision (should two mobile stations select the same random number) it is possible to use for the identification either the number of requested time slots or the priority or the time slot number of the packet random access (PRA) time slot (which refers to the time slot which the mobile station used for requesting a channel). These parameters are not shown in Figure 8.

[0041] The table in Figure 9 shows the bit contents of the control time slot presented in Figure 8 if the application system is the GSM. The bits indicating the number of requested time slots as well as those indicating the priority are optional.

[0042] So far we have described an embodiment of the inventive system mainly from the point of view of a base station. Let us now consider the transmission from a mobile station to a base station. The base station schedules the reservation of an uplink channel. It has the knowledge of free and reserved channels and that information is transmitted in every downlink control burst, as explained above. The bitmap consists of 8 bits, one for each time slot in a TDMA frame if the frame is a TDMA frame with 8 time slots. The reserved channels are marked with bit 1 and idle channels with bit 0. If the network is not using all 8 time slots for the packet transmission service, then only those channels that are used may be marked idle. The rest of the channels are treated as if they were reserved, ie. bit 1 is sent.

[0043] Referring to Figure 10. A mobile station which has data in its buffer and wants to send it monitors the control bursts sent in the downlink C time slots. Monitoring is continued until the bitmap shows that an uplink channel is marked idle. As soon as the idle channel is found, an access burst (channel request) according to Figure 10 is transmitted in an I time slot marked idle. This burst carrying the packet random access burst PRA is randomly selected as one of four, for example, if the frame used is four bursts. The packet random access PRA is similar to the access burst in the GSM system, for example, with a long training sequence. Then the data part of the burst will not include a random number as usual but those bits will be replaced by the PRA bits. Because of the long training sequence a mobile station which does not know the exact timing advance is able to send a PRA burst without problems. Possible collisions occurring when more than one mobile stations request a channel in the same time slot are handled with a back-off algorithm. An access burst consists of a random number sent back by the base station in the acknowledge burst, a number indicating how many time slots the mobile station wants, a four-level priority number, and finally a bit indicating whether or not the time slots have to be consecutive. The requirement for consecutive time slots is needed to support certain mobile classes. There might be a mobile station capable of handling, say, two packet time slots if they are consecutive in a TDMA frame but not if the time slots are a distance apart.

[0044] Figure 11 shows the possible bit contents of the fields. The burst consists of at least 11 bits. As soon as a base station receives an access burst PRA, it sends a packet access grant PAG in a downlink control burst C. If multiple consecutive access bursts are received before the next packet access grant can be transmitted, the priority or random selection is used to assign the channel for a mobile station. If there are not as many time slots available as requested, the base station can give as many as there are free.

[0045] When a mobile station has received an acknowledge PAG sent by a base station for a channel request PRA it starts to transmit packet data on the reserved channel consisting of one or more time slots, up to the maximum amount. It is possible to transmit during one reservation at least 128 octets which is the usual X. 25 maximum packet size. 128 octets equals six 4-octet blocks. This means that the maximum amount of data transmitted during one reservation depends on the

number of time slots used and that there has to be a limit value set in case the transmission fails and a retransmission is required. The limit value has to be more than 6, because in the case of retransmission 6 frames will not be enough to transmit all.

[0046] Figure 12 shows a signalling chart for mobile originated packets. A mobile station MS sends a channel request PRA acknowledged by a base station in a packet access grant burst PAG. The mobile station transmits packet data in time slots of one frame and the base station acknowledges or sends a retransmission request. This goes on until all packet data have been transmitted or time-out occurs.

[0047] Figure 13 is a state transition diagram illustrating the events in a mobile station during packet transmission from a base station to the network. When the data buffer is full, the mobile station goes from idle state to receive state and receives the information in the first control time slot from the base station. It consults the bitmap to see whether there are any free channels, and if not, checks the information in the next control time slot. This goes on until a free channel is found. Immediately after that, a channel request is sent on the free channel and if the base station acknowledges, packet data is transmitted on the dedicated channel. If no acknowledge is received, the mobile station returns to receive control time slots and search for a free channel.

[0048] Figure 14 illustrates a case where a network sends packet data addressed to a mobile station MS. A base station initiates a downlink transmission by sending a packet paging P in a control time slot C. The packet paging includes the mobile station identity and the reserved time slots. These time slots begin in the next TDMA frame. As soon as the MS receives the packet paging it starts receiving in the defined time slots.

[0049] Packet pagings are transmitted in every consecutive time slot of a downlink control sequence to inform mobile stations about incoming packets. This means that a mobile station must listen to all packet paging channels in order to find out if there are packets coming to it. This of course uses energy stored in the mobile station's battery. To optimize the power consumption mobile stations can be divided into different paging groups according to the temporary identity or IMSI, for example. Then a mobile station has to listen to only one time slot in a TDMA frame instead of all the time slots. There can be eight time slots, so it is more practical to listen to one time slot only. The paging frequency can be still decreased to support discontinuous reception DRX. This, however, increases the delay and therefore the DRX should be a selectable mode for a mobile station. The DRX power saving function can also be combined with the paging burst used in the present GSM system by adding the code "incoming packet" in the burst. Then a mobile station will listen to standard pagings and the code will inform it about an incoming packet transmission. Then the mobile station will start listening to the packet paging channel P and receive the necessary information from that channel. Of course, the network needs to know whether the mobile station is listening to the standard paging channel or the packet paging channel. The mobile station sends this information in a short management message.

[0050] If the base station does not receive an ARQ acknowledge in a certain number of frames, say, in seven frames, it draws the conclusion that the mobile station is not receiving frames correctly. Then the packet paging will be repeated.

[0051] Figure 15 shows a mobile station state transition diagram for the case presented in Figure 14. Understanding the diagram is easy on the basis of the description related to Figure 14, so further explanations are not needed. It is, however, pointed out that most of the time the mobile station is receiving control bursts and determining if there is a packet data transmission coming to it.

[0052] The frame used in the data link layer may be variable in length. A maximum length of, say, 128 octets, as in the X.25 protocol, can be chosen. A variable length reduces the number of acknowledges in the link layer and thus the number of reservations.

[0053] The system may be implemented in many ways within the scope of the invention defined by the claims set forth below. For example, the control time slots need not be as shown in Figure 3 but they can be moved diagonally, as illustrated by Figure 16.

[0054] In each frame, the control time slot C is moved forward one time slot, thus creating a diagonal pattern of control time slots both in the uplink and downlink frames as shown in Figure 16. A dedicated frame, however, still consists of a control time slot C and four information time slots I, as in the case illustrated by Figure 3.

Claims

1. A time division multiple access (TDMA) radio telephone system for transmitting packet data <u>over a packet radio connection</u> comprising:

    a base station and a mobile station, and
    at least one logical channel comprising a plurality of TDMA slots for transmitting packet data communication between the base station and the mobile station <u>over a packet radio connection,</u> individual ones of the TDMA slots of the at least one logical channel each occurring in a succession of physical TDMA frames, the at least one logical channel being reserved dynamically for packet data transmission according to need from the channels of one of the succession of TDMA frames, the number of reserved packet data channels being variable according to need,

    whereby the at least one logical channel in-

cludes a control channel (C) comprising a plurality of control slots and an information channel (I) comprising a plurality of information slots, wherein the control slots are temporally separated by consecutive information slots which occur in successive physical TDMA frames.

2. A system according to claim 1, wherein the control channel (C) includes an acknowledge/retransmission request burst (ARQ) for indicating error-free received data.

3. A system according to claim 1 or claim 2, wherein the logical channel is a downlink logical channel for transmitting from the base station to the mobile station, and the control channel (C) is capable of transmitting packet paging (PP) data for informing the mobile station of incoming packet data.

4. A system according to claim 3, wherein the control channel (C) is capable of transmitting a packet access grant PAG signal for acknowledging a channel reservation request (PRA) transmitted from the mobile station.

5. A system according to claim 4, wherein the packet access grant (PAG) signal includes a bitmap indicating which time slots have been reserved for uplink packet data transmission.

6. A system according to claim 3 or claim 4, wherein the packet paging (PP) data includes a bitmap indicating which time slots are reserved for downlink packet data transmission.

7. A system according to any preceding claim, responsive to a channel reservation request (PRA) in the form of a system access type burst and including information on how many time slots the mobile station wants to be reserved for packet data transmission.

8. A system according to claim 4 wherein in the downlink direction the acknowledge/retransmission request burst (ARQ) is part of a combined control channel burst (C) which includes both a packet paging (PP) and a packet access grant (PAG).

9. A system according to claim 3, wherein in the downlink direction the acknowledge/retransmission request burst (ARQ) is part of a control burst (C) which also includes a packet paging (PP).

10. A system according to claim 2 wherein in the downlink direction the acknowledge/retransmission request burst (ARQ) is part of a control burst (C) which also includes a packet access grant (PAG).

11. A system according to any of claims 8, 9 or 10, wherein the control burst (C) includes a bitmap indicating free and reserved logical channels in the uplink direction.

12. A system according to claims 9 and 10 wherein the packet paging (PP) and the packet access grant (PAG) signal are sent in alternate time slots of the control channel (C) and both bursts include an identifier with which a mobile station can distinguish one from the other.

13. A system according to claims 9 and 10 wherein only packet access grant (PAG) signals are sent in the time slots of the control channel (C) if there are no packet pagings (PP) to send and the burst includes an identifier with which a mobile station can distinguish one from the other.

14. A system according to any preceding claim wherein for transmitting packet data from a mobile station to a base station the mobile station is adapted to monitor control bursts transmitted on the downlink channel until a free channel dedicated for information transfer is identified in the bitmap,

in a time slot of said identified channel the mobile station is adapted to transmit a channel reservation request (PRA), and in response to receiving a packet access grant (PAG) signal from the base station the mobile station is adapted to transmit packet data on the identified channel.

15. A system according to claim 14, wherein the channel reservation request (PRA) signal comprises data indicative of a mobile station identifier, the number of time slots required for packet data transmission, and the priority of the request.

16. A system according to claim 15, wherein the channel reservation request (PRA) signal further comprises data indicative of whether or not the time slots have to be consecutive.

17. A system according to any claim dependent on claim 3 , wherein a mobile station listens to packet pagings (PP) only on channel assigned to it.

18. A system according to claim 17 wherein on said channel, packet pagings (PP) are transmitted only in predetermined control time slots known to the mobile station and the mobile station listens to packet pagings (PP) only during those time slots.

19. A system according to any claim dependent on claim 3, wherein a mobile station listens to normal paging calls of the system for an identifier indicating an incoming packet data transmission, and responsive to detection of said identifier the mobile station

starts listening to packet data pagings (PP).

20. A system according to claim 7, wherein the channel reservation request (PRA) signal includes an identifier indicating how many information channel time slots there has to be immediately one after the other.

21. A system according to any claim dependent on claim 3 wherein a packet paging (PP) is transmitted in every time slot of a TDMA frame.

22. A system according to any of the preceding claims, wherein the information slots include packet data.

Patentansprüche

1. Funktelefonsystem mit Zeitmultiplex-Vielfachzugriff (TDMA) zum Übertragen von Paketdaten über eine Paketfunkverbindung, mit:

   - einer Basisstation und einer Mobilstation sowie
   - mindestens einem logischen Kanal mit mehreren TDMA-Schlitzen zum Übertragen einer Paketdatenkommunikation zwischen der Basisstation und der Mobilstation über eine Paketfunkverbindung, wobei einzelne der TDMA-Schlitze des mindestens einen logischen Kanals jeweils in einer Abfolge physikalischer TDMA-Rahmen auftreten, wobei der mindestens eine logische Kanal dynamisch für Paketdatenübertragung entsprechend den Erfordernissen aus den Kanälen eines der Abfolge von TDMA-Rahmen reserviert wird, wobei die Anzahl reservierter Paketdatenkanäle entsprechend den Erfordernissen variabel ist;
   - wobei der mindestens eine logische Kanal einen Steuerkanal (C) mit mehreren Steuerschlitzen und einen Informationskanal (I) mit mehreren Informationsschlitzen beinhaltet, wobei die Steuerschlitze durch aufeinanderfolgende Informationsschlitze, wie sie in aufeinanderfolgenden physikalischen TDMA-Rahmen auftreten, zeitlich getrennt sind.

2. System nach Anspruch 1, bei dem der Steuerkanal (C) einen Bestätigungs/Neuübertragungs-Anforderungsburst (ARQ) zum Anzeigen fehlerfrei empfangener Daten beinhaltet.

3. System nach Anspruch 1 oder Anspruch 2, bei dem der logische Kanal ein logischer Abwärtskanal zum Senden von der Basisstation zur Mobilstation ist und der Steuerkanal (C) Paketfunkruf(PP)daten zum Informieren der Mobilstation über eingehende Paketdaten übertragen kann.

4. System nach Anspruch 3, bei dem der Steuerkanal (C) ein Signal zur Paketzugriffsgewährung, PAG, zum Bestätigen einer von der Mobilstation gesendeten Kanalreservierungsanforderung (PRA) übertragen kann.

5. System nach Anspruch 4, bei dem das Signal zur Paketzugriffsgewährung (PAG) eine Bitkarte beinhaltet, die anzeigt, welche Zeitschlitze für Paketdaten-Aufwärtsübertragung reserviert wurden.

6. System nach Anspruch 3 oder Anspruch 4, bei dem die Paketfunkruf(PP)daten eine Bitkarte beinhalten, die anzeigt, welche Zeitschlitze für Paketdaten-Abwärtsübertragung reserviert sind.

7. System nach einem der vorstehenden Ansprüche, das auf eine Kanalreservierungsanforderung (PRA) in Form eines Bursts vom Systemzugriffstyp, die Information dazu enthält, wieviele Zeitschlitze die Mobilstation für Paketdatenübertragung reserviert haben möchte, reagiert.

8. System nach Anspruch 4, bei der Bestätigungs/Neuübertragungs-Anforderungsburst (ARQ) in der Abwärtsstreckung Teil eines kombinierten Steuerkanalbursts (C) ist, der sowohl einen Paketfunkruf (PP) als auch eine Paketzugriffsgewährung (PAG) enthält.

9. System nach Anspruch 3, bei dem der Bestätigungs/Neuübertragungs-Anforderungsburst (ARQ) in der Abwärtsrichtung Teil eines Steuerbursts (C) ist, der auch einen Paketfunkruf (PP) enthält.

10. System nach Anspruch 2, bei dem der Bestätigungs/Neuübertragungs-Anforderungsburst (ARQ) in der Abwärtsstrecke Teil eines Steuerbursts (C) ist, der auch eine Paketzugriffsgewährung (PAG) enthält.

11. System nach einem der Ansprüche 8, 9 oder 10, bei dem der Steuerburst (C) eine Bitkarte enthält, die freie und reservierte logische Kanäle in der Aufwärtsrichtung anzeigt.

12. System nach den Ansprüchen 9 und 10, bei dem der Paketfunkruf (PP) und das Signal der Paketzugriffsgewährung (PAG) in abwechselnden Zeitschlitzen des Steuerkanals (C) gesendet werden und beide Bursts eine Kennung beinhalten, durch die eine Mobilstation sie voneinander unterscheiden kann.

13. System nach den Ansprüchen 9 und 10, bei dem nur Signale einer Paketzugriffsgewährung (PAG) in den Zeitschlitzen des Steuerkanals (C) gesendet werden, wenn keine Paketfunkrufe (PP) zu senden

sind, und die Bursts eine Kennung beinhalten, durch die eine Mobilstation die einen von den anderen unterscheiden kann.

14. System nach einem der vorstehenden Ansprüche, bei dem die Mobilstation zum Übertragen von Datenpaketen von ihr zu einer Basisstation so ausgebildet ist, dass sie im Abwärtskanal übertragene Steuerbursts überwacht, bis in der Bitkarte ein freier Kanal erkannt wird, der speziell zur Informationsübertragung zugewiesen wird, wobei die Mobilstation in einem Zeitschlitz des identifizierten Kanals dazu angepasst wird, eine Kanalreservierungsanforderung (PRA) zu senden, und wobei auf den Empfang eines Signals zur Paketzugriffsgewährung (PAG) von der Basisstation die Mobilstation so angepasst wird, dass sie Paketdaten im identifizierten Kanal sendet.

15. System nach Anspruch 14, bei dem das Signal der Kanalreservierungsanforderung (PRA) Daten enthält, die die Kennung einer Mobilstation, die Anzahl der für Paketdatenübertragung erforderlichen Zeitschlitze und die Priorität der Anforderung anzeigen.

16. System nach Anspruch 15, bei dem das Signal der Kanalreservierungsanforderung (PRA) ferner Daten enthält, die anzeigen, ob die Zeitschlitze aufeinanderfolgend sein müssen oder nicht.

17. System nach jedem beliebigen vom Anspruch 3 abhängigen Anspruch, bei dem eine Mobilstation nur in einem ihr zugewiesenen Kanal auf Paketfunkrufe (PP) horcht.

18. System nach Anspruch 17, bei dem im genannten Kanal Paketfunkrufe (PP) nur in vorbestimmten Steuerzeitschlitz gesendet werden, die der Mobilstation bekannt sind, und diese nur während dieser Zeitschlitze auf Paketfunkrufe (PP) horcht.

19. System nach jedem beliebigem vom Anspruch 3 abhängigen Anspruch, bei dem eine Mobilstation in normalen Funkruf-Anrufen des Systems nach einer Kennung horcht, die eine eingehende Paketdatenübertragung anzeigt, und die Mobilstation auf die Erfassung der Kennung hin damit beginnt, nach Paketdaten-Funkrufen (PP) zu horchen.

20. System nach Anspruch 7, bei dem das Signal der Kanalreservierungsanforderung (PRA) eine Kennung enthält, die anzeigt, wieviele Informationskanal-Zeitschlitze unmittelbar aufeinanderfolgen müssen.

21. System nach jedem beliebigen vom Anspruch 3 abhängigen Anspruch, bei dem in jedem Zeitschlitz eines TDMA-Rahmens ein Paketfunkruf (PP) übertragen wird.

22. System nach einem der vorstehenden Ansprüche, bei dem die Informationsschlitze Paketdaten enthalten.

Revendications

1. Système de radiotéléphone à accès multiple par répartition dans le temps (TDMA) destiné à transmettre des données par paquets sur une connexion radio par paquets comprenant :

    une station de base et une station mobile, et au moins un canal logique comprenant une pluralité de tranches de temps à accès TDMA destinées à transmettre une communication de données par paquets entre la station de base et la station mobile sur une connexion radio par paquets, des tranches individuelles parmi les tranches à accès TDMA du au moins un canal logique apparaissant chacune dans une suite de trames à accès TDMA physiques, le au moins un canal logique étant réservé dynamiquement pour une transmission de données par paquets conformément aux besoins des canaux d'une trame parmi la succession de trames à accès TDMA, le nombre des canaux de données par paquets réservés étant variable conformément aux besoins,
    d'où il résulte que le au moins un canal logique comprend un canal de commande (C) comprenant une pluralité de tranches de commande et un canal d'informations (I) comprenant une pluralité de tranches d'informations, dans lequel les tranches de commande sont séparées dans le temps par des tranches d'informations consécutives qui apparaissent dans des trames à accès TDMA physiques successives.

2. Système selon la revendication 1, dans lequel le canal de commande (C) comprend une salve de demande d'accusé de réception/demande de retransmission (ARQ) destinée à indiquer des données reçues dépourvues d'erreurs.

3. Système selon la revendication 1 ou la revendication 2, dans lequel le canal logique est un canal logique de liaison descendante destiné à transmettre depuis la station de base vers la station mobile, et le canal de commande (C) est capable de transmettre des données de recherche de personne par paquets (PP) en vue d'informer la station mobile des données de paquet entrant.

4. Système selon la revendication 3, dans lequel le canal de commande (C) est capable de transmettre

un signal d'accord d'accès par paquets PAG afin d'accuser réception d'une demande de réservation de canal (PRA) transmise depuis la station mobile.

5. Système selon la revendication 4, dans lequel le signal d'accord d'accès par paquets (PAG) comprend une mappe de bits indiquant quelles tranches de temps ont été réservées pour une transmission de données par paquets de liaison montante.

6. Système selon la revendication 3 ou la revendication 4, dans lequel des données de recherche de personne par paquets (PP) comprennent une mappe de bits indiquant quelles tranches de temps sont réservées pour une transmission de données par paquets de liaison descendante.

7. Système selon l'une quelconque des revendications précédentes, répondant à une demande de réservation de canal (PRA) sous forme d'une salve de type d'accès de système et comprenant des informations sur le nombre des tranches de temps que la station mobile souhaite voir réserver pour la transmission de données par paquets.

8. Système selon la revendication 4, dans lequel dans le sens de la liaison descendante, la salve d'accusé de réception/demande de retransmission (ARQ) fait partie d'une salve de canal de commande combinée (C) qui comprend à la fois une recherche de personne par paquets (PP) et un accord d'accès par paquets (PAG).

9. Système selon la revendication 3, dans lequel dans le sens de la liaison descendante, la salve d'accusé de réception/demande de retransmission (ARQ) fait partie d'une salve de commande (C) qui comprend également une recherche de personne par paquets (PP).

10. Système selon la revendication 2, dans lequel, dans le sens de la liaison descendante, la salve d'accusé de réception/demande de retransmission (ARQ) fait partie d'une salve de commande (C) qui comprend également un accord d'accès par paquets (PAG).

11. Système selon l'une quelconque des revendications 8, 9 ou 10, dans lequel la salve de commande (C) comprend une mappe de bits indiquant des canaux logiques libres et réservés dans le sens de la liaison montante.

12. Système selon les revendications 9 et 10, dans lequel la recherche de personne par paquets (PP) et le signal d'accord d'accès par paquets (PAG) sont émis dans des tranches de temps alternées dans le canal de commande (C) et les deux salves comprennent un identificateur avec lequel une station mobile peut établir la distinction de l'un et de l'autre.

13. Système selon les revendications 9 et 10, dans lequel seuls les signaux d'accord d'accès par paquets (PAG) sont émis dans les tranches de temps du canal de commande (C) s'il n'y a pas de recherches de personnes par paquets (PP) à émettre et la salve comprend un identificateur avec lequel une station mobile peut établir la distinction de l'un et de l'autre.

14. Système selon l'une quelconque des revendications précédentes, dans lequel, pour transmettre des données par paquets depuis une station mobile vers une station de base, la station mobile est conçue pour surveiller des salves de commande transmises sur le canal de liaison descendante jusqu'à ce qu'un canal libre spécialisé pour un transfert d'informations soit identifié dans la mappe de bits,

dans une tranche de temps dudit canal identifié, la station mobile est conçue pour transmettre une demande de réservation de canal (PRA), et en réponse à la réception d'un signal d'accord d'accès par paquets (PAG) de la station de base, la station mobile est conçue pour transmettre des données par paquets sur le canal identifié.

15. Système selon la revendication 14, dans lequel le signal de demande de réservation de canal (PRA) comprend des données indicatives d'un identificateur de station mobile, le nombre de tranches de temps requises pour la transmission de données par paquets, et la priorité de la demande.

16. Système selon la revendication 15, dans lequel le signal de demande de réservation de canal (PRA) comprend en outre des données indicatives du fait que les tranches de temps doivent être ou non consécutives.

17. Système selon l'une quelconque des revendications dépendantes de la revendication 3, dans lequel une station mobile écoute des recherches de personnes par paquets (PP) uniquement sur un canal qui lui est affecté.

18. Système selon la revendication 17, dans lequel sur ledit canal, des recherches de personnes par paquets (PP) ne sont transmises que dans des tranches de temps de commande prédéterminées connues de la station mobile et la station mobile écoute les recherches de personnes par paquets (PP) uniquement durant ces tranches de temps.

19. Système selon l'une quelconque des revendications dépendantes de la revendication 3, dans lequel une station mobile écoute des appels de recherches de personnes normaux du système pour

un identificateur indiquant une transmission de données par paquets entrantes, et en réponse à la détection dudit identificateur, la station mobile commence à écouter les recherches de personnes des données par paquets (PP).

20. Système selon la revendication 7, dans lequel le signal de demande de réservation de canal (PRA) comprend un identificateur indiquant combien de tranches de temps de canaux d'informations doivent être disposées immédiatement l'une après l'autre.

21. Système selon l'une quelconque des revendications dépendantes de la revendication 3, dans lequel une recherche de personne par paquets (PP) est transmise dans chaque tranche de temps d'une trame à accès TDMA.

22. Système selon l'une quelconque des revendications précédentes, dans lequel les tranches d'informations comprennent des données par paquets.

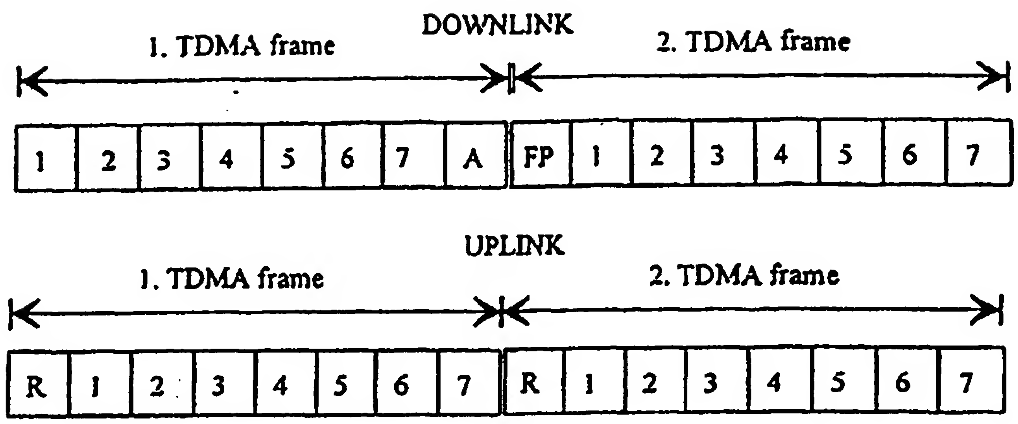
DOWNLINK
1. TDMA frame
2. TDMA frame
1
2
3
4
5
6
7
A
FP
1
2
3
4
5
6
7
UPLINK
1. TDMA frame
2. TDMA frame
R
1
2
3
4
5
6
7
R
1
2
3
4
5
6
7

Fig. 1

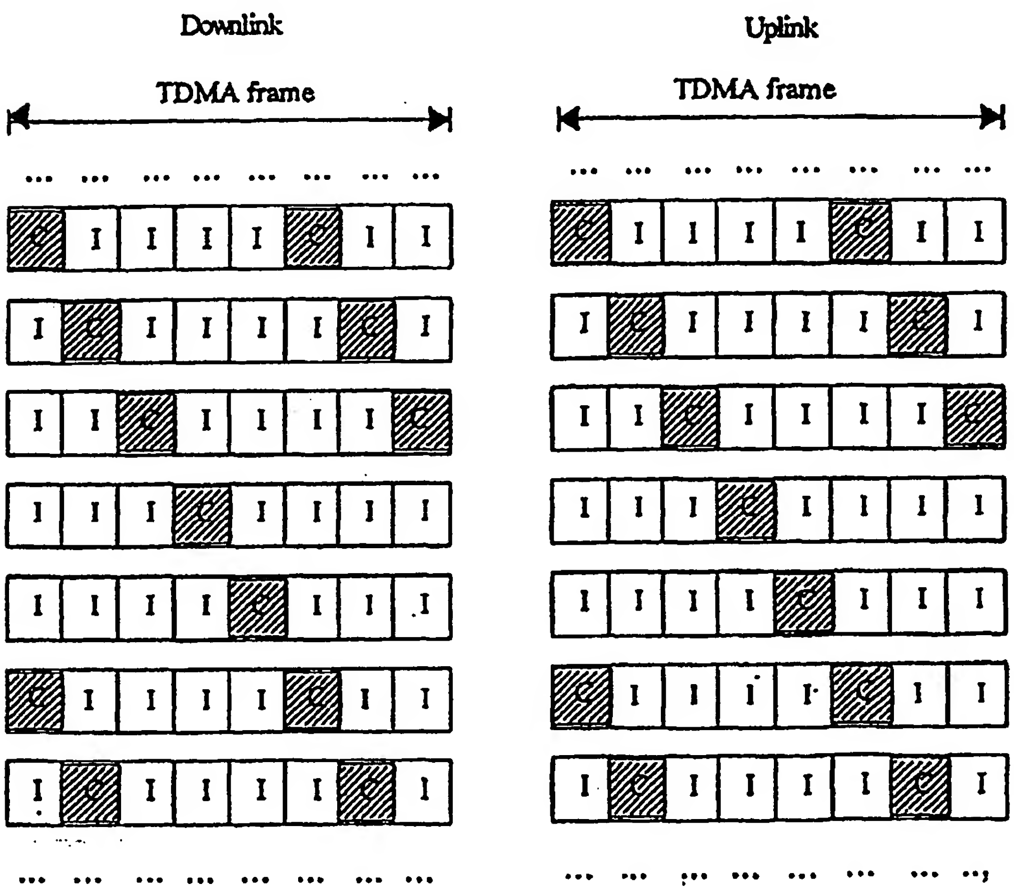
Downlink
TDMA frame
Uplink
TDMA frame

Fig. 16

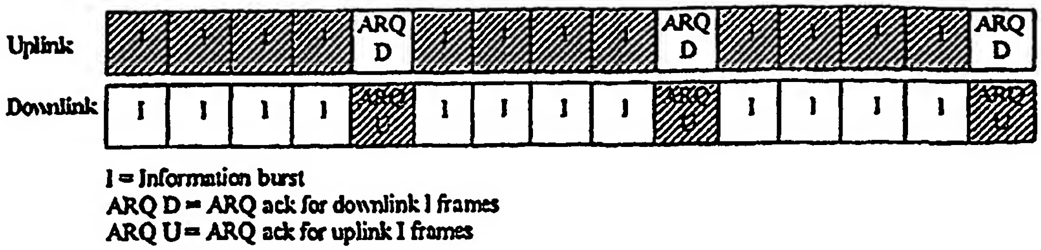
Uplink
Downlink
ARQ D
ARQ U
I = Information burst
ARQ D = ARQ ack for downlink I frames
ARQ U = ARQ ack for uplink I frames

Fig. 2

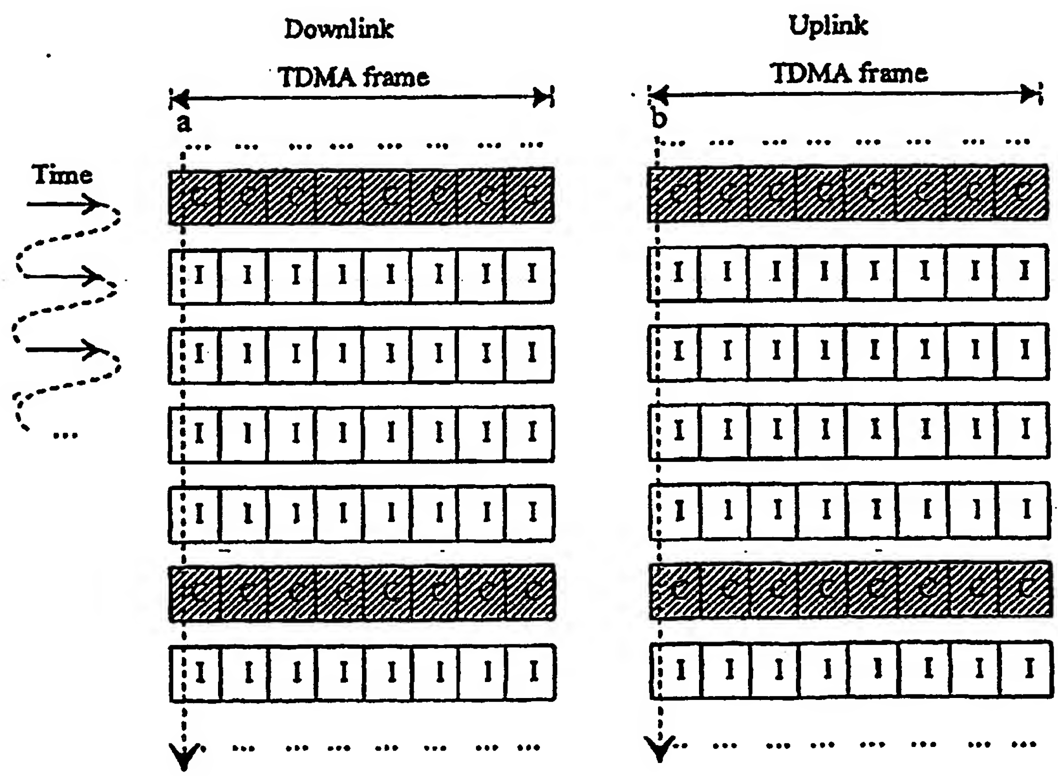
Downlink
TDMA frame
Uplink
TDMA frame
a
b
Time

Fig. 3

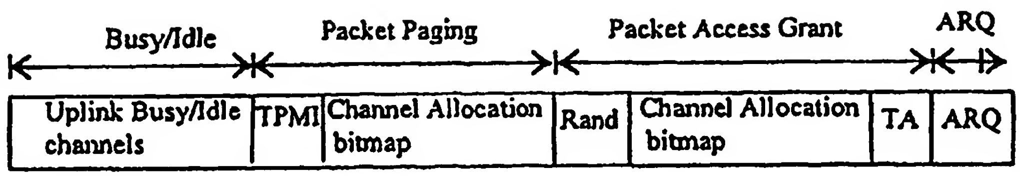

Fig. 4

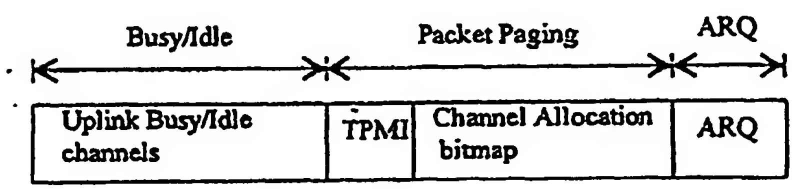

Fig. 6

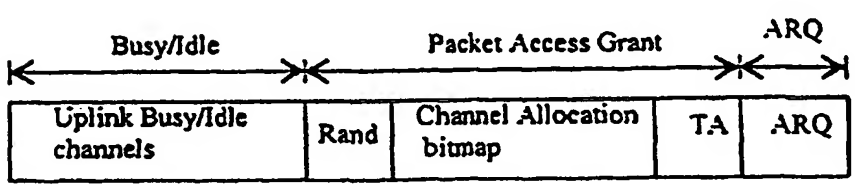

Fig. 8

FIELD CONTENTS	POSSIBLE NUMBER OF DATA BITS
bitmap of free/reserved uplink channels	8 bits
TMPI (temporary packet mobile ID)	25 bits
channel allocation bitmap (for paging)	max 8 bits
random number	8 bits
channel allocation bit map (for acknowledge)	max 8 bits
timing advance TA	6 bits
automatic retransmission request ARQ	12 bits

Fig. 5

FIELD CONTENTS	POSSIBLE NUMBER OF DATA BITS
TMPI (temporary packet mobile ID)	max 25 bits
channel allocation bit map	8 bits
ARQ acknowledge (L1 ARQ)	12 bits
bitmap of free uplink channels	8 bits

Fig. 7

FIELD CONTENTS	POSSIBLE NUMBER OF DATA BITS
random number included in PRA	5 bits (or 12 if modified access burst)
(number of requested time slots)	3 bits
(priority))	2 bits or more
channel allocation bitmap	8 bits
timing advance TA	6 bits
ARQ acknoqledge (L1 ARQ)	12 bits
bitmap of free uplink channels	8 bits

Fig. 9

FIELD CONTENTS	POSSIBLE NUMBER OF DATA BITS
random number (as in GSM)	5 bits or more
number of time slots needed	3 bits
priority (4 levels)	2 bits
requirement for consecutive time slots	1 bits

Fig. 11

Random number	No. of time slots	Priority	Consec.

Fig. 10

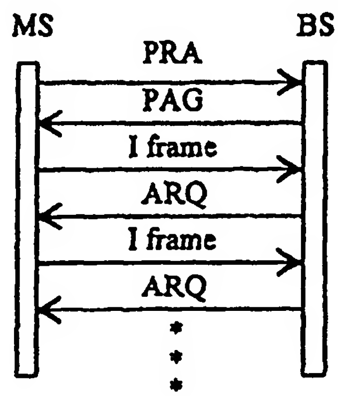

Fig. 12

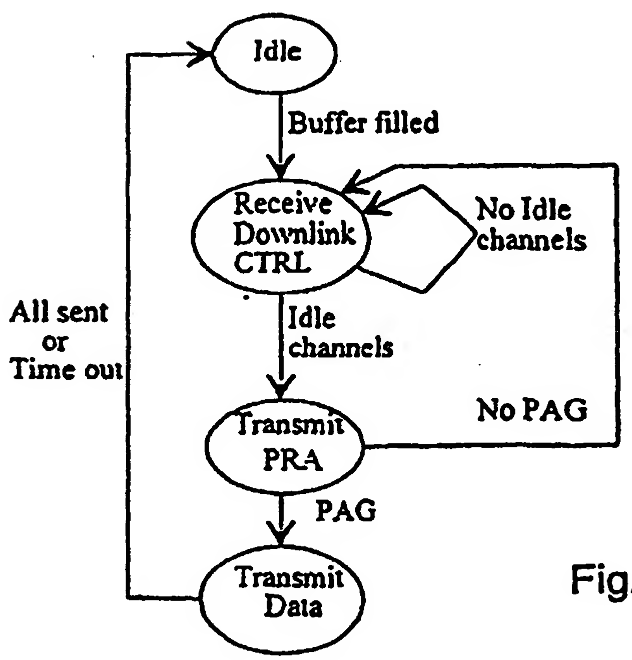

Fig. 13

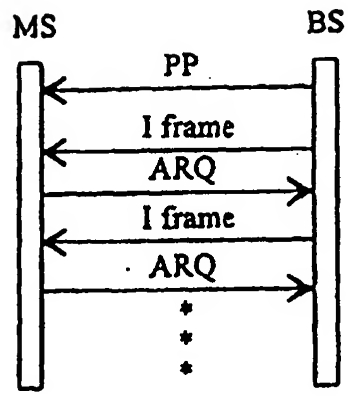
MS
BS
PP
I frame
ARQ
I frame
ARQ

Fig. 14

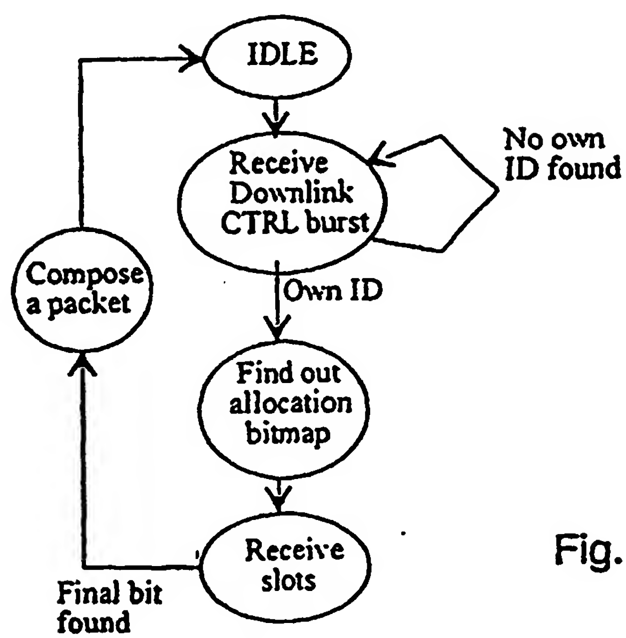
IDLE
Receive Downlink CTRL burst
No own ID found
Own ID
Find out allocation bitmap
Receive slots
Final bit found
Compose a packet

Fig. 15